

Improved Fire Resistance Test Method for Belt Materials

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A moderately scaled apparatus was developed for determining the fire resistance characteristics of mine conveyor belts and similar type materials. The test method overcomes the limitations of existing laboratory-scale methods and provides a measure of both ignitability and flammability in quantitative terms. Data are presented for nine belt materials, and fire resistance ratings are proposed in terms of the flame spread rate, heat release rate, and critical ignitor heat flux.

CONVEYOR BELT fires can present a serious hazard in the confined environment of an underground coal mine. To minimize this hazard, Federal regulations require the use of acceptable fire resistant conveyor belts and suitable belt slippage sequence switches, fire warning devices, and fire suppression systems.¹ The Federal Schedule 2G fire resistance test² has been used for many years for the approval of mine conveyor belts by the Bureau of Mines and, more recently, by the Mining Safety and Health Administration (MSHA). However, this test method has serious scale limitations, which prevent any reliable data extrapolation to a realistic mine fire situation. Also, it does not provide a measure of the important combustion parameters for deriving meaningful fire resistance ratings.

The inadequacy of small-scale belt fire tests was demonstrated in the works by Mitchell³ and Warner.⁴ Both investigators showed that certain neoprene (NP) and polyvinyl chloride (PVC) belts, which had been approved by Schedule 2G, were nevertheless capable of propagating flame over their entire length when full-scale fire conditions were simulated. The fire resistance test described in this report was developed to overcome the limitations of the Schedule 2G method and to provide quantitative ratings

that could be correlated with practical fire situations. It features a moderate scale apparatus to permit measurement of combustibility properties during both ignition and flame propagation stages. A fire resistance index is proposed for rating different conveyor belts, and the ratings are compared with those obtained by other methods.

The conveyor belts examined in this work included fire resistant and non-fire-resistant types. Table 1 lists the various belts that were used in this work. Except for the non-fire-resistant rubber belt, all belts met the fire resistance requirements as defined by the MSHA Schedule 2G test.

EXPERIMENTAL APPARATUS AND PROCEDURES

FLAMMABILITY APPARATUS

The general design of the apparatus (Figure 1) was based upon data from full-scale fires conducted in the fire gallery at Factory Mutual under a Bureau contract.⁵ A scaled down version was arrived at considering geometrical similitude and designed to define ignitability and flammability properties of the belt when burned in a horizontal attitude. The test chamber was 48 by 48 by 168 cm and was equipped with an adjustable stainless steel rack for mounting the belt samples. Other components of the apparatus included an air ventilation system, a radiant panel for preheating the belt, a methane-oxygen ribbon burner for igniting the sample, and instrumentation for measuring air velocities, air and belt temperatures, flame spread rates, heat release rates, and relative smoke densities. The radiant panel was 40 cm square and consisted of three infrared heaters that were capable of producing heat fluxes of up to 1 cal/cm²-sec over the belt section being ignited. The ribbon burner had a base cross section of approximately 1 by 15 cm and provided a flame that impinged upon the leading edge of the belt extending approximately 8 cm over the top surface; burner output was <100 kcal/min in these experiments. Full apparatus details are given in Reference 6.

CALIBRATION OF IGNITOR

The methane-oxygen burner was calibrated in terms of the actual heat flux received by the belt using a total heat flux calorimeter. Figure 2 shows the measured flux distribution with an ignitor input of 50 kcal/min and chamber air velocity of 30 m/min. The incident flux was over 2 cal/cm²-sec at the upstream end of the belt and decayed exponentially to approximately 0.015 cal/cm²-sec at 20 cm downstream. Regression of these data gave the following relationship:

$$Q_{ign} = 4.06 \exp(-0.277x) \quad (1)$$

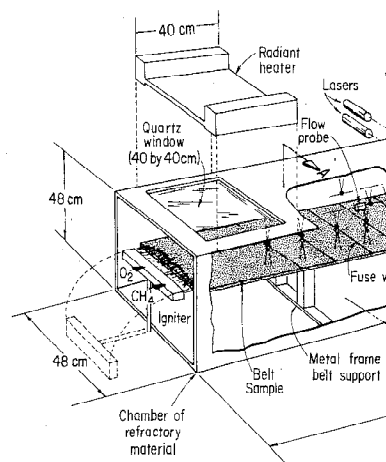


Figure 1. Schematic

where Q_{ign} is heat flux in cal/cm² belt surface. From this relation total heat received by the top distance of 8.2 cm from the upstream edge with the extent of flame impingement integrated mean of the flux distribution to characterize the ignitor source a mean heat flux (Q_{ign}) of 1.6 cal/cm² with an ignitor input of 50 kcal/min. This ignitor heat that is delivered to the belt surface is to be less than 10 percent

TEST PROCEDURE

To conduct an experiment, the radiant heaters are turned off, and the infrared preheaters are turned on. At this period, the burner flame is turned off. At the end of the preheating period, the ignitor is turned on and the sample is allowed to burn until the thermocouples and fuse wires indicate failure. Belt and chamber temperatures are recorded during the test.

Typical temperature history of the chamber ceiling are shown in Figure 3 for an ignitor input of 100 kcal/min. The spaced monitoring stations are shown in Figure 4. Only the first station (41 cm from the upstream edge being ignited, showed a

ations. It features a moderate combustibility properties during A fire resistance index is pro- the ratings are compared with

work included fire resistant and porous belts that were used in this test. In every belt, all belts met the fire SHA Schedule 2G test.

APPARATUS DETAILS

The test was based upon data from the Factory Mutual under a test that was arrived at considering combustibility and flammability in a horizontal attitude. The test chamber was equipped with an adjustable flow rate. Other components of the apparatus include a radiant panel for preheating the sample, oxygen and methane gas lines, air and belt temperatures, and active smoke densities. The radiant panel consists of three infrared heaters that deliver a mean heat flux of 1 cal/cm²-sec over the belt section. The cross section of approximately 168 cm is impinged upon the leading edge of the belt over the top surface; burner inputs. Full apparatus details are

shown in terms of the actual heat flux calorimeter. Figure 2 shows the burner input of 50 kcal/min and the heat flux was over 2 cal/cm²-sec at the burner. A portion of these data gave the

77x)

(1)

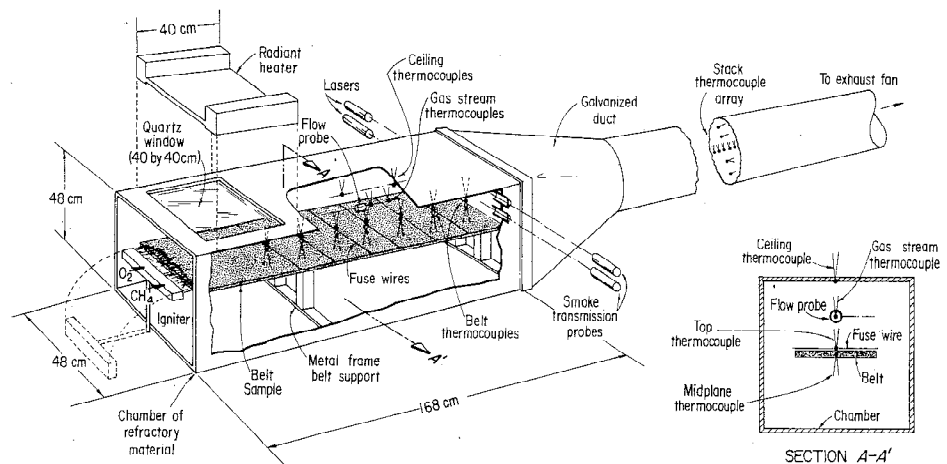


Figure 1. Schematic of belt flammability apparatus.

where Q_{ign} is heat flux in cal/cm²-sec and x is the reference distance on the belt surface. From this relationship, it was calculated that 90 percent of the total heat received by the top surface of the belt was concentrated over a distance of 8.2 cm from the upstream end. This distance was also consistent with the extent of flame impingement that was observed visually. The integrated mean of the flux distribution over this distance was used to characterize the ignitor source. Results of these calculations indicated that a mean heat flux (Q_{ign}) of 1.6 cal/cm²-sec was received by the belt at an ignitor input of 50 kcal/min. This value does not include the small amount of ignitor heat that is delivered to the bottom surface of the belt; we estimate this to be less than 10 percent of the total input.

TEST PROCEDURE

To conduct an experiment, the airflow is first preset at the desired rate, and the infrared preheaters are turned on for a predetermined period. After this period, the burner flame is applied to the belt and the radiant panel is turned off. At the end of the ignition period, the burner is removed and the sample is allowed to burn until the flame either extinguishes itself or the thermocouples and fuse wires indicate burning at the last monitoring station. Belt and chamber temperatures are continuously recorded throughout the test.

Typical temperature histories of the belt surface, gas stream, and chamber ceiling are shown in Figure 3 from a test with a PVC belt at an ignitor input of 100 kcal/min. These data were obtained at three of the equally spaced monitoring stations and include the fuse wire times. It is apparent that only the first station (41 cm), which was just beyond the preheated section being ignited, showed any detectable temperature rise during the

Fire Resistance Test

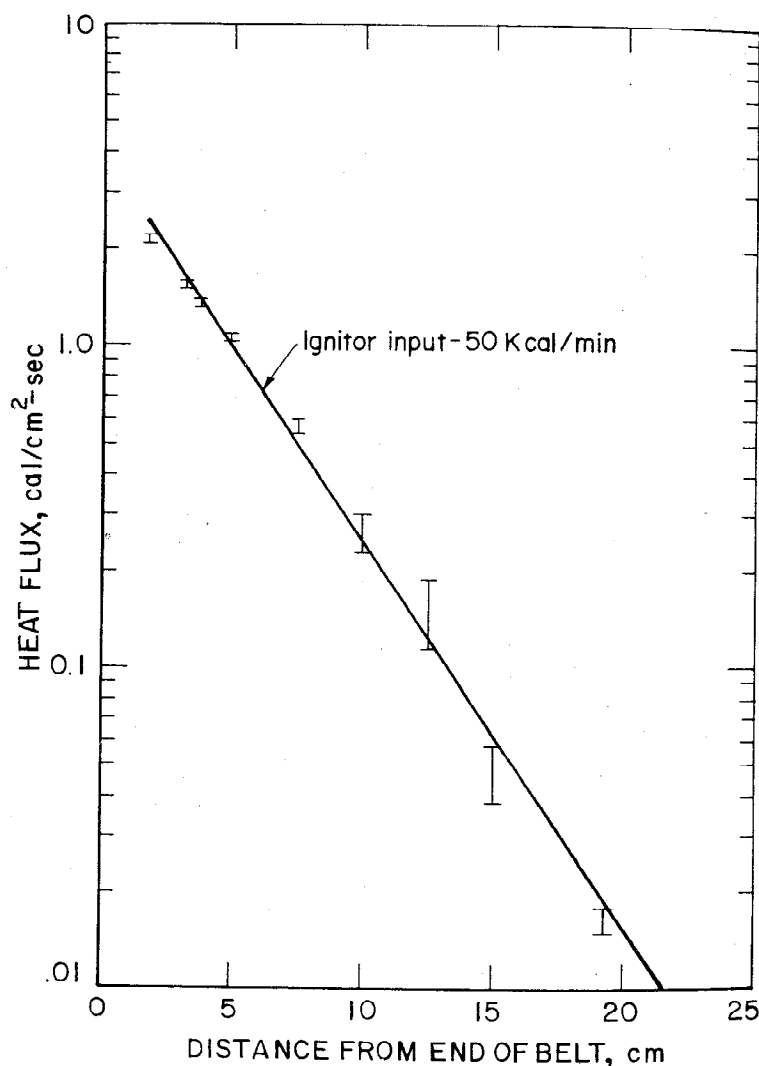


Figure 2. Incident heat flux vs. distance from upstream end of belt in calibration of burner flame ignitor source.

period of preheating (15 min) with the radiant panel. Immediately after application of the ignitor flame to the belt surface, the temperatures increased with time at each station as the burning became more fully developed. Arrival of flame at each station was indicated by an abrupt rise of the belt surface temperature and verified by comparison with the fuse wire break times. Flame spread rates were determined by linear regression of the flame arrival times and corresponding propagation distances. Heat release rates were determined from the variation of the upstream and downstream airflow temperatures.

123

124

TABLE 1. Description of Ply

Cover	Ply
Polyvinyl chloride (PVC):	
A-PVC	Cotton-nylon
B-PVC	Polyester
C-PVC	Polyester
D-PVC	Polyester-cotton nylon-rayon
Neoprene (NP):	
A-NP	Nylon
B-NP	Nylon-polyester
C-NP	Nylon-cotton, nylon-rayon
Styrene butadiene rubber (SBR):	
A-FRR (fire resistant)	Nylon
B-NFRR (non-fire resistant)	Nylon

* Formulated to meet Canadian specifications

EFFECTS OF

The effects of test variables on the fire resistance of a fire-resistant belt (A-PVC) that met these data showed that belt flame spread was a strong function of the radiant heat flux upon the ignitor (burner) heat input. The effects of the latter four variables are shown in Table 2 where the proposed (ref) values are also indicated.

At the proposed test conditions of 25 kcal/cm²-sec and duration (≤ 20 min), the fire resistance was only slightly and had little effect was overshadowed by the radiant heat flux (25-100 kcal/min). At the selected mean heat flux (1.6 cal/cm²-sec) the radiant flux that could be developed coal fire⁷ and was not sufficient to ignite combustibles. Thus, this heat flux level is that corresponding to the 100 kcal/cm²-sec and overly severe.

Both belt width and height are important. The back varies with the width of the belt and the distance to the chamber ceiling. For the test, the belt width was approximately 23 cm and belt height was 100 cm. These corresponded to a belt width/ceiling to belt ratio of 0.23, which was found in full-scale testing.⁵ The exponent of heat transfer is ill-

TABLE 1. Descriptions of Mine Conveyor Belts

Cover	Ply	Vendor	Trade name/code
Polyvinyl chloride (PVC):			
A-PVC	Cotton-nylon	Fenner America	Fennaplast/S-1942
B-PVC	Polyester	Scandura	Goldline II/Type 3500
C-PVC	Polyester	Georgia Duck	PV 500 A*
D-PVC	Polyester-cotton, nylon-rayon	Clouth (West Germany)	Duoply/630-2
Neoprene (NP):			
A-NP	Nylon	Goodyear	Mesa-N/804142
B-NP	Nylon-polyester	Goodyear	Mesa-R/804242
C-NP	Nylon-cotton, nylon-rayon	Clouth (West Germany)	Duoply/E630-2
Styrene butadiene rubber (SBR):			
A-FRR (fire resistant)	Nylon	Goodyear	Glide Mesa SBR/2126
B-NFRR (non-fire resis- tant)	Nylon	Goodyear	Pylon/315

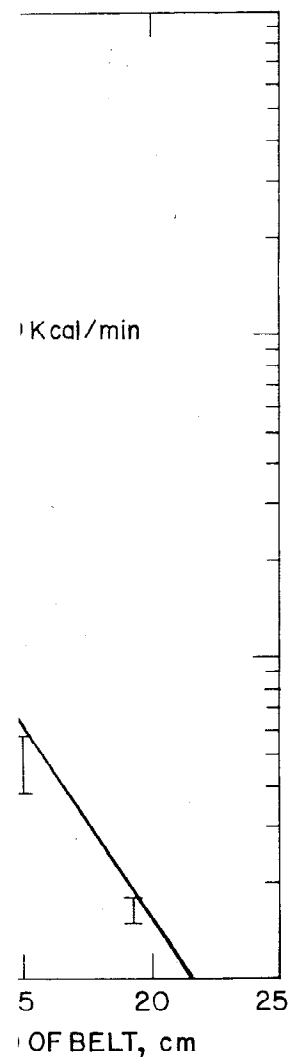
* Formulated to meet Canadian specifications.

EFFECTS OF TEST VARIABLES

The effects of test variables were determined using a moderately fire resistant belt (A-PVC) that met the Schedule 2G requirements. Essentially, these data showed that belt flammability in the proposed apparatus was not a strong function of the radiant preheat flux but was greatly dependent upon the ignitor (burner) heat input, air velocity, and belt width and height. The effects of the latter four variables on flame spread rate are shown in Table 2 where the proposed (reference) test conditions for this test method are also indicated.

At the proposed test conditions, variations in the intensity (≥ 0.2 cal/cm²-sec) and duration (≤ 20 min) of the radiant preheat flux promoted ignition only slightly and had little effect on the flame spread rate. This small effect was overshadowed by the large effect of the ignitor flame heat input (25–100 kcal/min). At the selected ignitor heat input of 50 kcal/min, the mean heat flux (1.6 cal/cm²-sec) on the belt surface was typical of the thermal radiative flux that could result in the immediate area of a fully developed coal fire⁷ and was more than adequate for igniting most combustibles. Thus, this heat flux level is a realistic ignition condition, whereas that corresponding to the 100 kcal/min input would generally be atypical and overly severe.

Both belt width and height are important variables, since radiation feedback varies with the width of the burning surface and proximity of the belt to the chamber ceiling. For the present test chamber, a belt width of approximately 23 cm and belt height of 34 cm were optimum for flame propagation. These corresponded to a belt height/chamber height ratio of 0.74 and a belt width/ceiling to belt ratio of 1.6 and were roughly consistent with those found in full-scale testing.⁵ The relatively great effect of the radiative component of heat transfer is illustrated in Figure 4. Here, the calculated

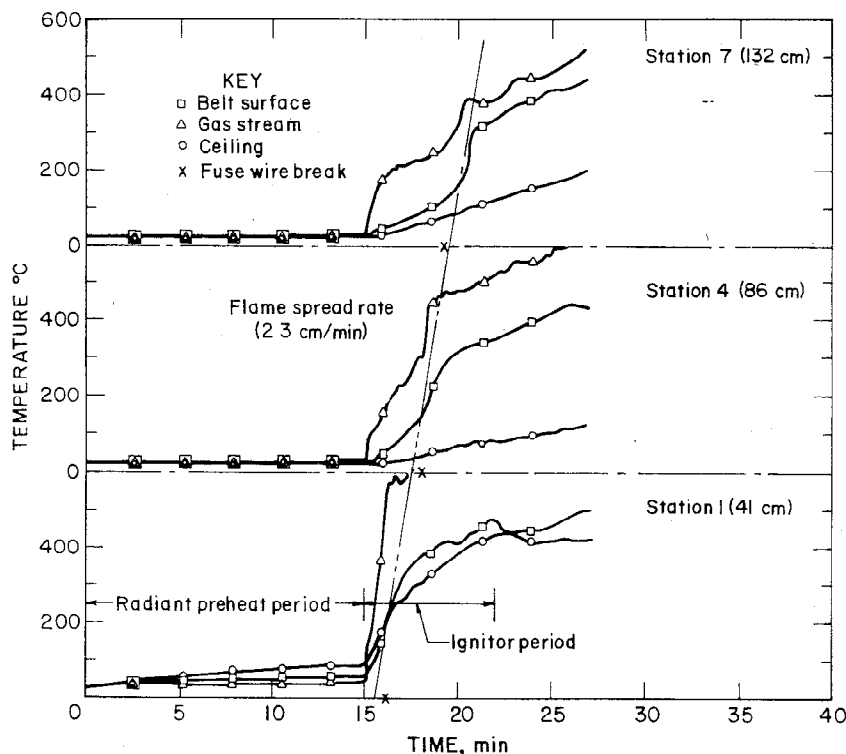


cm end of belt in calibration of burner

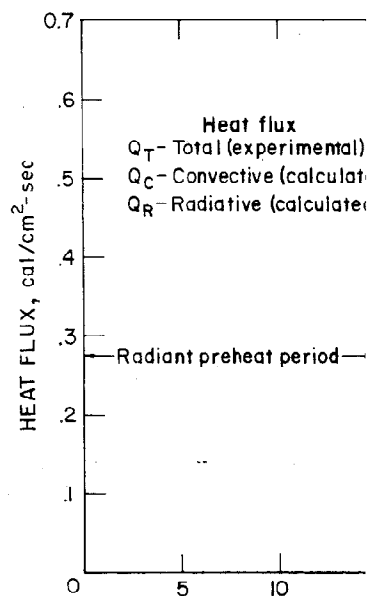
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TABLE 2. Effects of Test Variables on Flame Spread of a Fire Resistant Belt (A-PVC)^a

Belt width (cm)	Flame spread rate (cm/min)	Belt height (cm)	Flame spread rate (cm/min)	Ignitor input (kcal/min)	Flame spread rate (cm/min)	Air velocity (m/min)	Flame spread rate (cm/min)
15	0-8.8	23	NI ^c	25	NI	0	8.2
23 ^b	12.8	30.5	NI	50 ^b	12.2	15	8.5
30.5	14.3	34 ^b	12.2	100	23	30 ^b	12.2
		40.5	1.4			30-60	12.7-80
						60	NI

^a Data obtained changing indicated variable at reference test conditions.^b Reference test conditions with radiant preheat flux of 0.1 cal/cm²-sec for 15 min.^c No ignition or no propagation beyond ignited section.Figure 3. Temperature-time profiles at three monitoring stations in flammability test with A-PVC belt (23 by 152 cm) at an ignitor input of 100 kcal min⁻¹.

radiative (Q_R) and convective (Q_C) components are compared to the measured total heat flux (Q_T) at the belt surface, 90 cm from the ignited end. Q_C was calculated from measurements of belt surface (T_b) and gas stream (T_g) temperatures between stations, and Q_R was determined by difference and by an independent calculation according to Hottel:⁸

Figure 4. Comparison of measured heat flux components during burning of 30 m min⁻¹, and belt height of 30 cm.

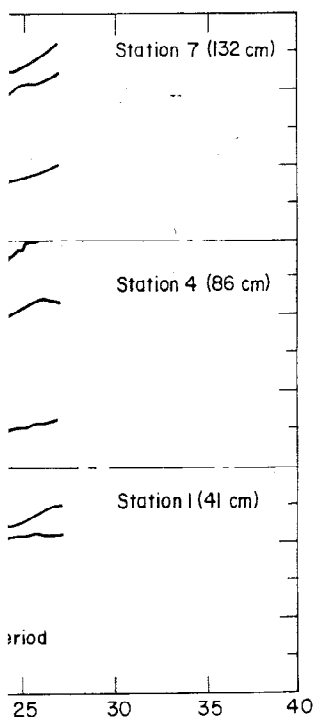
where T is temperature (°K), σ is Stefan Boltzman constant, and F is radiation view factor. As shown, Q_C counts largely for the total heat flux during the ignition period, but Q_R counts largely for the total heat flux during the radiant preheat period.

An air velocity of 30 m/min was used in this test, although this velocity was not used in the calculation of flame spread. Note in Table 2 that the velocity was increased greatly with increase in flame spread rate. Thus, the velocity condition to be measured is the velocity condition to be measured.

of a Fire Resistant Belt (A-PVC)^a

Flame spread rate (cm/min)	Air velocity (m/min)	Flame spread rate (cm/min)
NI	0	8.2
12.2	15	8.5
23	30 ^b	12.2
	30-60	12.7-80
	60	NI

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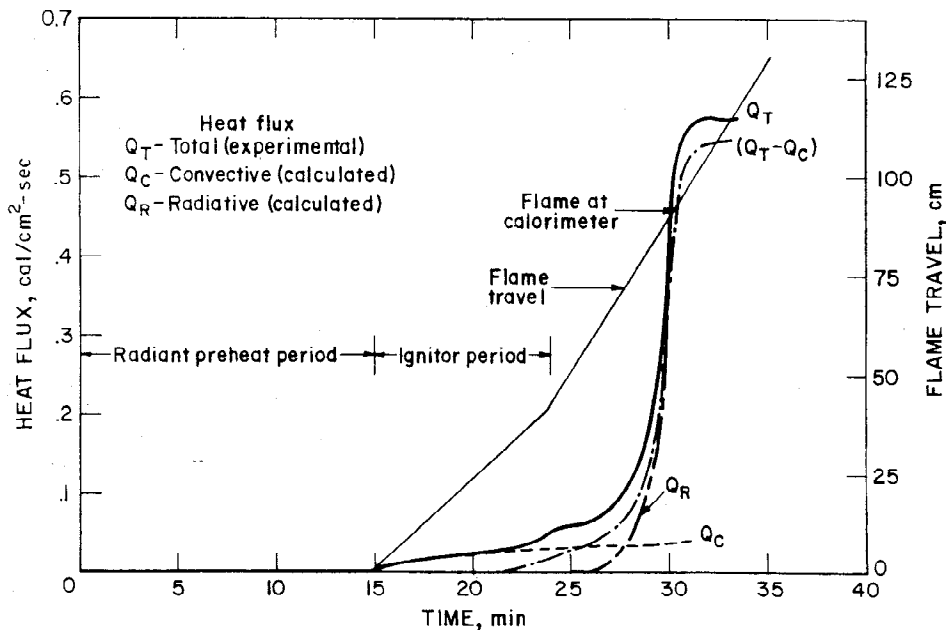


Figure 4. Comparison of measured total heat flux with calculated convective and radiative flux components during burning of A-NP belt at an ignitor input of 50 kcal min⁻¹, air velocity of 30 m min⁻¹, and belt height of 35 cm.

$$Q_T = Q_C + Q_R \quad (2)$$

$$Q_C = h(T_g - T_b) \quad (3)$$

$$Q_R = \sigma F_{12} T_f^4 \quad (4)$$

where T is temperature (°K), h is heat transfer coefficient (cal/cm²-sec-°K), σ is Stefan Boltzman constant (1.35×10^{-12} cal/cm²-sec-°K⁴), and F_{12} is a radiation view factor. As shown in Figure 4, convective heat transfer accounts largely for the total thermal flux transmitted downstream during the ignition period, but radiative heat transfer comprises about 90 percent of the total measured flux when the flame reaches the calorimeter.

An air velocity of 30 m/min was selected as the reference test condition, although this velocity was not necessarily optimum for maximum possible flame spread. Note in Table 2 that sustained ignition was not obtained when the velocity was increased to 60 m/min but that flame spread rates increased greatly with increased velocity when ignition was initially affected at a lower velocity. Thus, the flame spread hazard must be qualified by the velocity condition to be meaningful.

TABLE 3. Summary of Flammability Index Data for Red Oak and Various Conveyor Belts at Reference Test Conditions in New Belt Flammability Apparatus. Ignitor Input of 50 kcal/min (1.6 cal/cm²-sec) and Air Velocity of 30 m/min.

Belt Type	Flame spread rate, FS (cm/min)	Heat release rate, Q_f (cal/cm ² -min)	Critical ignitor input, I (cal/cm ²)	Flammability index, FI^a	Normalized flammability index, FI^{*b}
Red oak standard	20.8	230	145	33	100
Goodyear (B-NFRR)	10.9	213	145	16	48
Goodyear (A-NP)	10.6	165	240	7.3	22
F. America (A-PVC)	12.2	122	335	4.4	13
Goodyear (A-FRR)	5.8	60	335	1.0	3.0
Goodyear (B-NP)	7.2	76	820	0.7	2.1
Scandura (B-PVC)	7.3	75	1,295	0.4	1.2
Georgia Duck (C-PVC) ^c	0 (4.0)	NI (65)	>1,440 (≤ 1345)	0 (0.2)	0 (0.6)
Clouth (D-PVC) ^d	0, 4.6	NI, 71	>2,400, 865	0, 0.4	0, 1.2
Clouth (C-NP)	0	NI	>2,400	0	0

NI No ignition.

$$^a FI \propto \frac{FS \times Q_f}{I}$$

^b Normalized FI with respect to red oak.

^c Ignitor input of 100 kcal/min (3.2 cal/cm²-sec) for value in parenthesis.

^d Only one ignition in four trials.

FIRE RESISTANCE RATINGS BY NEW APPARATUS

The reference test conditions specified in Table 2 were used to compare fire resistance ratings for the belts. Three factors were considered in defining these ratings:

- Critical heat input for sustained ignition (I).
- Flame spread rate at critical ignitor heat input (FS).
- Heat release rate at critical ignitor heat input (Q_f).

Since ignition was a function of the magnitude and duration of the ignitor heat flux, a time-integrated flux ($Q_{ign} \times t$) was used to define the I ignition factor; here, the exposure time (t) was varied and Q_{ign} was fixed at 1.6 cal/cm²-sec unless noted otherwise. To obtain a combined fire resistance rating that reflects the contribution of all three factors, the following empirical flammability index (FI) is proposed:

$$FI = \frac{FS \times Q_f}{I} \quad (5)$$

Table 3 summarizes the data obtained for various conveyor belts together with those for red oak as a reference material. It is apparent that fire resistance ratings can be misleading if both ignition and flame propagation stages are not considered. For example, the A-PVC and A-FRR belts have the same I value but noticeably different FS and Q_f values. Also, the

B-NFRR and A-NP belts have significantly different I and Q_f .

By the proposed rating scheme, the red oak standard was 100 for the red oak standard belt and near 0 for the most fire resistant belts. It is difficult to ignite and generate a fire under general conditions; that is, an unusual fire resistance rating. Intermediate FI^* values must be used for belts with intermediate FS , Q_f , and I values. For such belts, the flammability index under at least one test condition is sensitive to their FS and Q_f values. The fire resistance ratings were rounded to the nearest scale tests with the given belts.

COMPARISON WITH OTHER METHODS

Belt fire resistance ratings found by other methods in Table 4 show different ranking of fire resistance ratings. These differences are understandable considering the different test conditions.

The ASTM E-2863 oxygen index test is used for A-PVC, B-PVC, and C-PVC belts. The data trends in Table 4. It suffices to show a favorable mode for flame propagation associated with small-scale fire resistance ratings that are insufficiently high for the E-162 radiant panel method¹⁰ and, therefore, does not spread hazard in many cases. This is particularly for the A-NP and B-NFRR belts.

The Schedule 2G method² is used for A-PVC, B-PVC, and C-PVC belts as an inadequate ignition source. It can result in flame blowout. The fire resistance criterion was either very low or very high for all the approved belts. The flame duration below 1 min is a poor criterion. The method underestimates the fire resistance between fire resistant belts.

The Ohio University heat flux method¹¹ that the critical ignitor input is reflected in the heat release rate. The fire resistance is inconsistent for the A-NP and B-NFRR belts. The neoprene belt (A-NP) had approximately the same fire resistance as the red oak standard belt.

l Oak and Various Conveyor Belts
ty Apparatus. Ignitor Input of
city of 30 m/min.

Ignitor input, I (J/cm^2)	Flam- mability index, FI^*	Normalized flam- mability index, FI^{**}
145	33.	100
145	16	48
140	7.3	22
135	4.4	13
135	1.0	3.0
120	0.7	2.1
195	0.4	1.2
0 (≤ 1345)	0 (0.2)	0 (0.6)
1,865	0, 0.4	0, 1.2
0	0	0

in parenthesis.

RATINGS ATUS

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and Q_{ign} was fixed at 1.6
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(5)

for various conveyor belts
material. It is apparent that
ignition and flame propaga-
the A-PVC and A-FRR belts
 FS and Q_f values. Also, the

B-NFRR and A-NP belts have approximately the same FS value but significantly different I and Q_f values.

By the proposed rating scheme, the normalized flammability index (FI^*) was 100 for the red oak standard as compared to 48 for a non-fire resistant belt and near 0 for the most fire resistant belts. The latter belts were very difficult to ignite and generally required an ignitor flux greater than 1.6 $\text{cal/cm}^2\text{-sec}$; that is, an unusually severe ignition condition. Belts that give intermediate FI^* values must be considered suspect, depending upon their FS , Q_f , and I values. For such belts, it would be prudent to define their flammability index under at least two air velocity conditions to determine how sensitive their FS and Q_f values are to the ventilation flow. The order of the fire resistance ratings was roughly consistent with those indicated by full-scale tests with the given belt materials.⁵

COMPARISON WITH OTHER TEST METHODS

Belt fire resistance ratings by the present method are compared to those found by other methods in Table 4. It is apparent that each method gives a different ranking of fire resistance for the belt materials. The inconsistencies are understandable considering the deficiencies of each method.

The ASTM E-2863 oxygen index method⁹ gives ratings for the A-NP, A-PVC, B-PVC, and C-PVC belts that are inconsistent with most of the data trends in Table 4. It suffers from the fact that it relies upon the least favorable mode for flame propagation (downward direction) and the limitations associated with small-scale tests. Consequently this method yields ratings that are insufficiently conservative or discriminating. The ASTM E-162 radiant panel method¹⁰ also utilizes the downward mode of propagation and, therefore, does not provide conservative estimates of the flame spread hazard in many cases. This method gave questionable rankings, particularly for the A-NP and B-PVC belts.

The Schedule 2G method² has the usual small-scale limitations, as well as an inadequate ignition source and a velocity condition (90 m/min) that can result in flame blowout. Fire resistance reflected by the flame duration criterion was either very low for the non-fire-resistant belt (B-NFRR) or very high for all the approved fire resistant belts; belt approval criteria are flame duration below 1 min and glow duration below 3 min. Overall, this method underestimates the belt fire hazard and is poor for discriminating between fire resistant belts.

The Ohio University heat release method¹¹ suffers mainly from the fact that the critical ignitor input is not included and flame spread is only partly reflected in the heat release rate. Ratings by this method were particularly inconsistent for the A-NP and B-NP belts; note that the non-fire-resistant belt (B-NFRR) had approximately the same rating as a fire resistant neoprene belt (A-NP).

TABLE 4. Comparison of Fire Resistance Ratings for Conveyor Belts by Various Test Methods

Belt Type	ASTM ^a E-2863 O ₂ index (vol. %)	ASTM ^b E-162 flame spread index	MSHA ^c Schedule 2G flame duration (sec)	OSU ^d heat release rate (cal/cm ² -min)	BuMines flam- mability index FI* ^e
Goodyear (B-NFRR)	24	113	620	782	48
Goodyear (A-NP)	30	18	14	755	22
F. America (A-PVC)	24	64	1.5	282	13
Goodyear (A-FRR)	28	31	0	350	3
Goodyear (B-NP)	30	31	45	466	2.1
Scandura (B-PVC)	27	86	2	220	1.2
Georgia Duck (C-PVC)	26	39	2.5	190	0
Clouth (D-PVC)	36	NA	4	NA	< 1.2
Clouth (C-NP)	37	NA	0	NA	0

NA Not available.

^a Index defines critical O₂ concentration of propagation (Ref. 9).^b Index reflects flame spread and heat release (Ref. 10).^c Flame duration of <1 min and glow duration of <3 min are approval criteria (Ref. 2).^d Radiant heat flux of 3 watts/cm² (Ref. 11).^e Normalized flammability index at reference test conditions with ignitor input at 50 kcal/min.

Fire resistance ratings by the Bureau of Mines method overcome the serious deficiencies of the above small-scale methods and provide a more reliable measure of the potential fire hazard that may be practically encountered with mine conveyor belts. As stated earlier, the ratings are necessarily limited to the given ventilation flow condition (30 m/min), and increasing the airflow after sustained ignition can increase the flame spread rate; this is particularly important when the belt material appears to have marginal fire resistance. A great advantage of this test method is that it provides quantitative fire resistance ratings and permits comparison of the flame spread, heat release, and ignition factors that determine the potential belt fire hazard. Thus, one can compare belt ratings on the basis of a single factor and by the combined contribution of all three factors as indicated by the FI* index.

CONCLUSIONS

An improved belt fire resistance test method was developed that provides more reliable ratings than those obtained by MSHA's Federal Schedule 2G method and other laboratory-scale methods. The critical variables were air velocity, ignitor heat input (burner flame), belt width, and belt proximity to the top of the test chamber; the latter parameter controls the amount of radiation feedback to the burning belt, which is an important consideration in real fire situations. Results of this work indicated that an ignitor input of 50 kcal/min was adequate for igniting most belts and that a belt width/chamber width ratio of at least 0.5 and a belt height/chamber height ratio of about 0.75 were optimum for achieving sustained flame propagation; also, an air velocity of at least 30 m/min appeared necessary for

such evaluations, but ignition

Three criteria are recommended, namely, integrated ignitor spread rate, and heat release normalized flammability index with fire resistant rubber belt, but marginal fire resistance, and Both PVC and neoprene belts polyester or polyester-nylon (cass). The most fire resistant Duck), which was formulated man PVC and neoprene belts

¹ U.S. Code of Federal Regulations, Safety and Health Administration, Part 75 — Mandatory Safety and Health Standards, pp. 482-490.

² —, Subchapter D — for Permissibility; Fees; Part 18 — July 1, 1978, pp. 111-112.

³ Mitchell, D. W., Murphy, C. M., "Conveyor Belts," BuMines RI 7053, 1967.

⁴ Warner, B. L., "Suppression of Fire," Research Contract HO 122086 by 27-76, 1974, 105 pp.; available from PB 250 368/AS.

⁵ Buckley, J., "Conveyor Belt Fire," No. III, by Factory Mutual Research 1978, 68 pp.

⁶ Sapko, M. J., Mura, K. E., "Fire Hazard for Conveyor Belts," BuMines RI, 1967.

⁷ Chaiken, R. F., Singer, J. M., "Fire Flow," BuMines RI 8355, 1979, 32 pp.

⁸ Hottel, H. C., and A. F. Sarofim, 1967, p. 41.

⁹ American Society for Testing and Materials, "Standard Test Method for Oxygen Index Method," ASTM D 2839-77.

¹⁰ —, "Standard Test Method for Radiant Energy Source," ASTM E-106-77.

¹¹ Smith, C. C., "Measuring Fire Hazard," Technology, Vol. 8, No. 3 (1972), p. 13.

SHA ^c dule 2G ame ration sec)	OSU ^d heat release rate (cal/cm ² -min)	BuMines flam- mability index FI**
620	782	48
14	755	22
1.5	282	13
0	350	3
45	466	2.1
2	220	1.2
2.5	190	0
4	NA	< 1.2
0	NA	0

ion (Ref. 9).

(0).
3 min are approval criteria (Ref. 2).

conditions with ignitor input at 50

Mines method overcome the methods and provide a more l that may be practically en-ated earlier, the ratings are ow condition (30 m/min), and can increase the flame spread belt material appears to have of this test method is that it nd permits comparison of the s that determine the potential atings on the basis of a single l three factors as indicated by

N S

hod was developed that pro- tained by MSHA's Federal -scale methods. The critical (burner flame), belt width, and the latter parameter controls ng belt, which is an important of this work indicated that an igniting most belts and that a .5 and a belt height/chamber hieving sustained flame prop- n/min appeared necessary for

such evaluations, but ignition is more difficult at high velocities.

Three criteria are recommended for defining belt fire resistance ratings; namely, integrated ignitor heat flux for sustained propagation, flame spread rate, and heat release rate. By the proposed rating scheme, the normalized flammability index was 100 for red oak, approximately 50 for a non-fire resistant rubber belt, between 10 and 25 for belts of moderate or marginal fire resistance, and less than 10 for highly fire resistant belts. Both PVC and neoprene belts appeared to be more fire resistant with a polyester or polyester-nylon carcass than with a nylon or nylon-cotton carcass. The most fire resistant belts were an American PVC belt (Georgia Duck), which was formulated to meet Canadian specifications, and two German PVC and neoprene belts (Clouth).

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